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UTILITY PATENT APPLICATION TRANSMITTAL <i>(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))</i>	Attorney Docket No.	13DV13658
	First Inventor or Application Identifier	WHEAT
	Title	Method for Vapor Phase Aluminiding etc
	Express Mail Label No.	EL627656247US

APPLICATION ELEMENTS <i>See MPEP chapter 600 concerning utility patent application contents.</i>	ADDRESS TO: Assistant Commissioner for Patents Box Patent Application Washington, DC 20231
1. <input checked="" type="checkbox"/> * Fee Transmittal Form (e.g., PTO/SB/17) <i>(Submit an original and a duplicate for fee processing)</i> 2. <input checked="" type="checkbox"/> Specification [Total Pages <u>15</u>] - Descriptive title of the Invention - Cross References to Related Applications - Statement Regarding Fed sponsored R & D - Reference to Microfiche Appendix - Background of the Invention - Brief Summary of the Invention - Brief Description of the Drawings (if filed) - Detailed Description - Claim(s) - Abstract of the Disclosure 3. <input checked="" type="checkbox"/> Drawing(s) (35 U.S.C. 113) [Total Sheets <u>3</u>] (informal) 4. <input type="checkbox"/> Oath or Declaration [Total Pages <u>2</u>] (unsigned) a. <input type="checkbox"/> Newly executed (original or copy) b. <input type="checkbox"/> Copy from a prior application (37 C.F.R. § 1.63(d)) (for continuation/divisional with Box 16 completed) i. <input type="checkbox"/> DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).	5. <input type="checkbox"/> Microfiche Computer Program (Appendix) 6. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary) a. <input type="checkbox"/> Computer Readable Copy b. <input type="checkbox"/> Paper Copy (identical to computer copy) c. <input type="checkbox"/> Statement verifying identity of above copies
ACCOMPANYING APPLICATION PARTS 7. <input type="checkbox"/> Assignment Papers (cover sheet & document(s)) 8. <input type="checkbox"/> 37 C.F.R. § 3.73(b) Statement of Power of Attorney (when there is an assignee) 9. <input type="checkbox"/> English Translation Document (if applicable) 10. <input type="checkbox"/> Information Disclosure Statement (IDS)/PTO-1449 [Copies of IDS Citations] 11. <input type="checkbox"/> Preliminary Amendment 12. <input checked="" type="checkbox"/> Return Receipt Postcard (MPEP 503) (Should be specifically itemized) * Small Entity Statement filed in prior application, Status still proper and desired (PTO/SB/09-12) 13. <input type="checkbox"/> Certified Copy of Priority Document(s) (if foreign priority is claimed) 14. <input type="checkbox"/> Other: 15. <input type="checkbox"/> Other:	
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Signature	<i>David L. Narciso</i>	Date	Sept 26, 2000

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TOTAL AMOUNT OF PAYMENT (\$ 690.00

Complete if Known

Application Number
Filing Date
First Named Inventor GARY E. WHEAT
Examiner Name
Group / Art Unit
Attorney Docket No. 13DV13658

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101 690	201 345	Utility filing fee	690
106 310	206 155	Design filing fee	
107 480	207 240	Plant filing fee	
108 690	208 345	Reissue filing fee	
114 150	214 75	Provisional filing fee	

SUBTOTAL (1) (\$ 690.00

2. EXTRA CLAIM FEES

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20	-20**		
2	-3**		
Multiple Dependent			

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103 18	203 9	Claims in excess of 20
102 78	202 39	Independent claims in excess of 3
104 260	204 130	Multiple dependent claim, if not paid
109 78	209 39	** Reissue independent claims over original patent
110 18	210 9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) (\$ 0

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
105 130	205 65	Surcharge - late filing fee or oath	
127 50	227 25	Surcharge - late provisional filing fee or cover sheet.	
139 130	139 130	Non-English specification	
147 2,520	147 2,520	For filing a request for reexamination	
112 920*	112 920*	Requesting publication of SIR prior to Examiner action	
113 1,840*	113 1,840*	Requesting publication of SIR after Examiner action	
115 110	215 55	Extension for reply within first month	
116 380	216 190	Extension for reply within second month	
117 870	217 435	Extension for reply within third month	
118 1,360	218 680	Extension for reply within fourth month	
128 1,850	228 925	Extension for reply within fifth month	
119 300	219 150	Notice of Appeal	
120 300	220 150	Filing a brief in support of an appeal	
121 260	221 130	Request for oral hearing	
138 1,510	138 1,510	Petition to institute a public use proceeding	
140 110	240 55	Petition to revive - unavoidable	
141 1,210	241 605	Petition to revive - unintentional	
142 1,210	242 605	Utility issue fee (or reissue)	
143 430	243 215	Design issue fee	
144 580	244 290	Plant issue fee	
122 130	122 130	Petitions to the Commissioner	
123 50	123 50	Petitions related to provisional applications	
126 240	126 240	Submission of Information Disclosure Stmt	
581 40	581 40	Recording each patent assignment per property (times number of properties)	
146 690	246 345	Filing a submission after final rejection (37 CFR § 1.129(a))	
149 690	249 345	For each additional invention to be examined (37 CFR § 1.129(b))	

Other fee (specify) _____

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SUBTOTAL (3) (\$ 0

SUBMITTED BY

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Signature	Date	
	Sept 26, 2000	

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METHOD FOR VAPOR PHASE ALUMINIDING
INCLUDING A MODIFYING ELEMENT

FIELD OF THE INVENTION

This invention relates to the coating of substrates with a modified aluminum-containing coating, and, more particularly, to vapor phase aluminiding with an added modifying element.

BACKGROUND OF THE INVENTION

In an aircraft gas turbine (jet) engine, air is drawn into the front of the engine, compressed by a shaft-mounted compressor, and mixed with fuel. The mixture is burned, and the hot combustion gases are passed through a turbine mounted on the same shaft. The flow of combustion gas turns the turbine by impingement against an airfoil section of the turbine blades and vanes, which turns the shaft and provides power to the compressor. The hot exhaust gases flow from the back of the engine, driving it and the aircraft forwardly.

The hotter the combustion and exhaust gases, the more efficient is the operation of the jet engine. There is thus an incentive to raise the combustion and exhaust gas temperatures. The maximum temperature of the combustion gases is normally limited by the materials used to fabricate the airfoils of the turbine vanes and turbine blades, upon which the hot combustion gases impinge. In current engines, the turbine vanes and blades are made of nickel-based superalloys, and can operate at temperatures of up to about 1800-2100°F.

Many approaches have been used to increase the operating temperature limit of the turbine blades and vanes to their current levels. For example, the composition and processing of the base materials themselves have been improved. Solidification is controlled to produce directionally oriented structures that orient the grain boundaries parallel to the major stress axis or eliminate the grain boundaries entirely, and also take

advantage of the most suitable crystallographic orientations of the metal. Physical cooling techniques are used, such as providing internal cooling passages through which cooling air is passed.

5 In another approach, protective coatings are applied to the internal and external surfaces of the airfoils of the turbine blades and vanes. Aluminide diffusion coatings are used for the internal surfaces, and aluminide diffusion coatings or overlay coatings are used on the external surfaces. A ceramic thermal barrier coating layer may also overlie the aluminum-containing coating on the external surfaces.

10 Although these internal and external protective layers provide improved resistance to environmental damage of the turbine components and the ability to operate at higher temperatures, there is an opportunity for improvement. Thus, there is a need for improved protective coating systems and methods for their application that extend the capabilities of the turbine components even further. The present invention fulfills this need, and further provides related advantages.

BRIEF SUMMARY OF THE INVENTION

15 The present invention provides a method for coating an article with an aluminide coating that is modified with at least one other element to enhance oxidation resistance and other environmental performance of the coating. The method may be used on a wide variety of articles, with the airfoils of gas turbine blades and vanes being of particular interest. The coating method uses known procedures, modified to permit the deposition
20 of the modifying element. The amount of the modifying element introduced into the coating may be controlled through the deposition parameters. The approach is compatible with other techniques for improving aluminide coatings, such as platinum aluminiding, and with the subsequent application of an overlying ceramic thermal barrier coating.

25 A method for coating an article comprises the steps of providing the article having a surface, and preparing a coating source comprising an aluminum halide, a fluoride or an iodide of a modifying element as a source of the modifying element, and

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a carrier gas. The modifying element is selected from the group consisting of zirconium, hafnium, and yttrium, and mixtures thereof, with zirconium and hafnium preferred. The method further includes contacting the coating source to the article, and heating the coating source and the article to a coating temperature of at least about 1850°F, preferably from about 1850°F to about 2000°F, for a period of time sufficient to permit aluminum and the modifying element to coat onto the surface of the article to produce a modified aluminide coating. The article may have a layer of platinum or other noble metal applied thereto prior to the contacting step, resulting in a modified platinum aluminide coating. Thus, zirconium-modified diffusion aluminides, zirconium-modified platinum aluminides, hafnium-modified diffusion aluminides, and hafnium-modified platinum aluminides are of particular interest.

The presence of the modifying element improves the oxidation and corrosion resistance of the aluminide layer. The amount of the modifying element in the coating is controllable through the ratio of the aluminum halide to the fluoride of the modifying element. For example, in the case of the zirconium modifying element, the zirconium content of the aluminide coating may be controlled over the range of tenths of a percent up to about 6 percent by weight.

In one embodiment, the article is an airfoil of a gas turbine blade or gas turbine vane, and the article is made of a nickel-base superalloy. The aluminum halide is preferably aluminum trifluoride, and the coating source may further include the elemental form of solid aluminum. The coating source may also include the elemental form of the solid modifying element. In each case, the "elemental" form where present is the pure element or an alloy thereof.

The fluoride of the modifying element is preferred over the iodide. The fluoride of the modifying element is a solid at room temperature. The fluoride of the modifying element may be provided separated from the article surface, such as in a powder form. It may instead or also be provided as a component of a slurry, paint, or the like applied to the surface of the article before the heating step. In either case, the fluoride of the modifying element decomposes upon heating and is reduced to the elemental form by the

aluminum. The elemental form of the modifying element then codeposits with the aluminum on the article surface and diffuses into the surface.

The fluoride (or an iodide) of the modifying element must be the source of the modifying element. (The elemental form of the modifying element may optionally be present as well, but it may not replace the fluoride of the modifying element.) The present approach has been found to be operable and most practical where the modifying element is supplied from its fluoride, although in some cases the iodide of the modifying element may be operable as well. The chlorides and bromides of the modifying element are not within the scope of the present invention, as they are not thermodynamically and kinetically suitable.

The present approach is operable to deposit a modified aluminide coating onto the surface of the article by the described modified vapor phase aluminiding process. The modified vapor phase aluminiding approach is preferably to alternative candidates for introducing the modifying element into the aluminide coating, because it is less labor intensive and consequently less expensive.

Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention. The scope of the invention is not, however, limited to this preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of a turbine blade;

Figure 2 is an enlarged schematic sectional view through the turbine blade of Figure 1, taken on lines 2-2;

Figure 3 is a block flow diagram of an approach for preparing a coated gas turbine airfoil;

Figure 4 is a schematic depiction of a first embodiment of a coating approach; and

Figure 5 is a schematic depiction of a second embodiment of a coating approach.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 depicts a component article of a gas turbine engine such as a turbine blade or turbine vane, and in this illustration a turbine blade 20. The turbine blade 20 is formed of any operable material, but is preferably a nickel-base superalloy. The turbine blade 20 includes an airfoil 22 against which the flow of hot combustion gas is directed. (The turbine vane has a similar appearance in respect to the pertinent portions.) The turbine blade 20 is mounted to a turbine disk (not shown) by a dovetail 24 which extends downwardly from the airfoil 22 and engages a slot on the turbine disk. A platform 26 extends longitudinally outwardly from the area where the airfoil 22 is integral with the dovetail 24. A number of internal passages optionally extend through the interior of the airfoil 22, ending in openings 28 in the surface of the airfoil 22. A flow of cooling air is directed through the internal passages, to reduce the temperature of the airfoil 22. The airfoil 22 may be described as having a root end 30 adjacent to the dovetail 24, and an oppositely disposed tip end 32 remote from the dovetail 24.

Figure 2 is a longitudinal section through the airfoil 22, showing one of the internal passages 34 extending through the interior of the airfoil 22. The internal passage 34 has an internal airfoil surface 36, and there is also an external airfoil surface 38 of the metallic portion of the airfoil 22. The airfoil surfaces 36 and/or 38 may optionally have a thin layer of platinum thereon, preferably deposited by electroplating.

The present approach may be used to deposit an internal protective layer 40 onto the internal airfoil surface 36, an external protective layer 46 onto the external airfoil surface 38, or both. The protective layers 40 and 46 are preferably from about 0.001 inch to about 0.003 inch thick, although they may be thicker or thinner. The protective layers 40 and 46 are formed by depositing a coating comprising aluminum and a modifying element onto the respective internal airfoil surface 36 or external airfoil surface 38, or both, so that a body of the airfoil 22 serves as a substrate 42. The coating is interdiffused

with the alloy of the substrate 42. During this processing, a separate step, and/or service of the component article at elevated temperature, the protective layers 40 and 46 are oxidized to form a protective aluminum oxide layer 43, sometimes termed a "scale". This protective aluminum oxide layer inhibits and slows subsequent corrosion and oxidation damage at the airfoil surfaces 36 and 38.

A ceramic thermal barrier coating 48 is optionally deposited overlying and contacting the external protective layer 46 (or aluminum oxide layer 43, if present). When the ceramic thermal barrier coating 48 is present, the protective layer 46 is known as a bond coat, and the protective layer 46 (and its aluminum oxide layer 43) and ceramic thermal barrier coating 48 are collectively termed a thermal barrier coating system 44.

The ceramic thermal barrier coating 48 is preferably from about 0.003 to about 0.010 inch thick, most preferably about 0.005 inch thick. (Figure 2 is not drawn to scale.) The ceramic thermal barrier coating 48 is preferably yttria-stabilized zirconia, which is zirconium oxide containing from about 2 to about 12 weight percent, preferably from about 4 to about 8 weight percent, of yttrium oxide. Other operable ceramic materials may be used as well. It may be deposited by any operable technique, such as physical vapor deposition or plasma spray.

Figure 3 is a block flow diagram of a preferred approach for practicing the invention. The article, in this case the airfoil 22, is provided, numeral 60. The turbine blade 20 and its airfoil 22 are preferably made of a nickel-base superalloy. A typical nickel-base alloy has a composition, in weight percent, of from about 1 to about 25 percent cobalt, from about 1 to about 25 percent chromium, from about 0 to about 8 percent aluminum, from 0 to about 10 percent molybdenum, from about 0 to about 12 percent tungsten, from about 0 to about 12 percent tantalum, from 0 to about 5 percent titanium, from 0 to about 7 percent rhenium, from 0 to about 6 percent ruthenium, from 0 to about 4 percent niobium, from 0 to about 0.2 percent carbon, from 0 to about 0.15 percent boron, from 0 to about 0.05 percent yttrium, from 0 to about 1.6 percent hafnium, balance nickel and incidental impurities. Specific compositions are known in the art. The turbine blade 20 and its airfoil are preferably as-cast structures, with an equiaxed,

directionally oriented polycrystalline, or single-crystal structure. The airfoil 22 may be previously coated with a layer of a noble metal such as platinum, so that the final modified aluminide is a modified platinum aluminide.

A coating source is prepared, numeral 62. The coating source comprises the elements and/or compounds that enter the coating reaction. The coating source preferably comprises an aluminum halide and a fluoride of the modifying element as a source of the modifying element. The aluminum halide is preferably aluminum trifluoride (AlF_3), although aluminum trichloride or other operable source may also be used. The modifying element is zirconium, hafnium, or yttrium, or mixtures thereof. The tetrafluorides of these modifying elements are the preferred sources, although during the reactions other fluorides may be produced and could therefore also be used as starting material sources for the modifying elements. The respective preferred tetrafluorides are zirconium tetrafluoride (ZrF_4), hafnium tetrafluoride (HfF_4), or yttrium tetrafluoride (YF_4), or mixtures thereof. (The iodides of the modifying elements may be used in some circumstances, but the chlorides and bromides are unsuitable and may not be used.) All of these compounds are solids at room temperature.

The aluminum halide is preferably provided in a loose powdered form. The tetrafluoride of the modifying element may be in a loose powdered form separated from the surface to be processed, or in a powdered form in a binder applied to the surface as will be discussed later. The coating source may optionally contain, and preferably does contain, the elemental solid form of aluminum (or its alloys) and/or the elemental solid form of the modifying element (zirconium, hafnium, and/or yttrium, in pure or alloyed form). (As used in this context, naming the element includes the pure element and its alloys.) For definiteness, the balance of the discussion of the method will focus on deposition of zirconium from zirconium tetrafluoride, but the approach is similar for the other modifying elements or combinations of the modifying elements.

The concentration of the modifying element in the final protective layer 40 or 46 depends upon the relative concentration of the aluminum halide and the fluoride of the modifying element. In the case that has been most extensively studied, the aluminum

halide is aluminum trifluoride and the fluoride of the modifying element is zirconium tetrafluoride. A weight ratio of aluminum trifluoride to zirconium tetrafluoride of about 1.4:1 produces a coating with about 1 percent by weight zirconium. A weight ratio of aluminum trifluoride to zirconium tetrafluoride of about 3:1 produces a coating with about 6 percent by weight zirconium. Intermediate and higher or lower amounts of zirconium may be produced with a ratio that is determined respectively by interpolation and extrapolation.

The coating source further includes a carrier gas that transports the other components of the coating source through the coating system. Argon gas is preferred as the carrier gas, but other gases such as hydrogen may be used in some circumstances.

Using the coating source, the protective coating is deposited onto the surface of the article, numeral 64. The deposition step 64 includes two substeps, contacting the coating source to the article, numeral 66, and heating the coating source and the article to a coating temperature of at least about 1850°F, more preferably from about 1850°F to about 2000°F, and most preferably from about 1925°F to about 1975°F, for a period of time sufficient to permit aluminum and the modifying element to coat onto the surface of the article, numeral 68. These substeps 66 and 68 are typically performed at least in part simultaneously, although some parts of the contacting substep 66 may be performed prior to the heating step 68 or vice versa.

Figures 4-5 illustrate two variations of a coating apparatus that may be used in the deposition step 64. These two forms of the coating apparatus will be discussed by way of illustration of the approach, although other structures and types of coating apparatus may be used. In each case, a coating apparatus 80 includes a retort 82 that is externally heated, here by schematically indicated electrical resistance heating coils 84. The articles to be coated, here the turbine blades 20, are supported on a shelf 86 in the upper portion of the retort 82.

The solid components of the coating source are placed into the lower portion of the retort 82 in the embodiment of Figure 4. The solid components are schematically

indicated by containers 88 of aluminum trifluoride, containers 90 of aluminum metal, and for the case where the modifying element is zirconium, containers 92 of zirconium tetrafluoride and containers 94 of zirconium metal sponge or powder. Other containers would be provided for mixtures of the modifying elements. The various solid components need not be separated into separate containers, but instead may be mixed together. The embodiment of Figure 5 is similar, except that the zirconium tetrafluoride is not provided separately from the turbine blade 20. Instead, the zirconium tetrafluoride powder is mixed with an organic binder and a carrier to form a paint slurry. The paint slurry is applied to the surface of the turbine blade 20 prior to insertion into the retort 82 and dried by evaporating the carrier. The zirconium tetrafluoride powder is in direct contact with the surface to be processed.

Upon heating of the retort 82 to the coating temperature, zirconium tetrafluoride sublimates (at about 1112°F) and the aluminum trifluoride remains as a solid but produces aluminum trifluoride gas. The presence of the aluminum and zirconium metals in elemental form ensure an excess of these elements in the coating source. The aluminum reduces the zirconium tetrafluoride. A flow 96 of the carrier gas, here argon, transports the mixture of reactive gases from the lower portion of the retort 82 to the upper portion and the turbine blades 20 to be coated. As indicated in Figures 4-5, the flow of coating gas may be through openings 98 in the shelf 86 to reach and coat the external airfoil surfaces 38. As indicated in Figure 5, the flow of coating gas may also or instead be through openings 100 in the shelf 86 that register with the internal passages 34 of the turbine blade 20, to reach and coat the internal airfoil surfaces 36. In both cases, the coating gas deposits aluminum and zirconium onto the exposed surfaces. Any unreacted coating gas is swept out of the retort 82 by the flow of the carrier gas. The coating process is continued as long as necessary to produce the desired thickness of the coatings 40 and 46.

At the elevated coating temperature of the deposition step 64, the deposited aluminum, modifying element, and any other co-deposited elements (as well as platinum, if present) interdiffuse with each other and with the metal of the substrate 42. The

diffusion continues upon exposure to elevated temperatures in service. The resulting layers are therefore diffused into the surfaces upon which they are deposited, and with increasing diffusion time become less distinct as separate layers. Figure 2 depicts the layers 40 and 46 as distinct layers for purposes of clarity in the illustration, but over time the interdiffused layers 40 and 46 become more like regions at the surfaces of the substrate 42.

Returning to the discussion of Figure 3, upon completion of the deposition step 64, the ceramic thermal barrier coating 48 is optionally deposited over the external aluminide protective layer 46, numeral 70. The ceramic thermal barrier coating 48 may be deposited by any operable technique, such as physical vapor deposition or plasma spray.

The present invention has been reduced to practice using the approach discussed in relation to Figures 3 and 4 to deposit zirconium-modified aluminides and hafnium-modified aluminides. The substrate was Rene' N5, a nickel-base superalloy which has a nominal composition in weight percent of about 7.5 percent cobalt, about 7 percent chromium, about 6.2 percent aluminum, about 6.5 percent tantalum, about 5 percent tungsten, about 1.5 percent molybdenum, about 3 percent rhenium, about 0.05 percent carbon, about 0.004 percent boron, about 0.15 percent hafnium, up to about 0.01 percent yttrium, balance nickel and incidental impurities. The substrate 42 was coated with a zirconium-modified diffusion aluminide protective layer about 0.0023 inch thick. Zirconium compositions ranging from about 0.1 weight percent to about 6.8 weight percent were produced. In separate trials, hafnium-modified diffusion aluminide coatings were prepared. Other studies have indicated that the use of the zirconium-modified aluminide layer or the hafnium-modified aluminide layer increases the life of the coated article substantially as compared with the non-modified aluminide layer. Even further improvements are obtained by using a zirconium-modified platinum aluminide layer or the hafnium-modified platinum aluminide layer.

Although a particular embodiment of the invention has been described in detail for purposes of illustration, various modifications and enhancements may be made

without departing from the spirit and scope of the invention. Accordingly, the invention is not to be limited except as by the appended claims.

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CLAIMS

What is claimed is:

1. A method for coating an article, comprising the steps of:
 providing the article having a surface;
 preparing a coating source comprising:
 an aluminum halide,
 a fluoride or an iodide of a modifying element as a source of the
 modifying element, the modifying element being selected from the group consisting of
 zirconium, hafnium, and yttrium, and combinations thereof, and
 a carrier gas;
 contacting the coating source to the article; and
 heating the coating source and the article to a coating temperature of at least about
 1850°F for a period of time sufficient to permit aluminum and the modifying element to
 coat onto the surface of the article.
2. The method of claim 1, wherein the step of providing the article includes
 the step of
 providing the article with a platinum-enriched surface region thereon.
3. The method of claim 1, wherein the article is an airfoil made of a nickel-
 base superalloy.
4. The method of claim 1, wherein the aluminum halide is aluminum
 trifluoride.
5. The method of claim 1, wherein the fluoride of the modifying element is
 used, and the fluoride of the modifying element is a tetrafluoride of the modifying
 element.
6. The method of claim 1, wherein the coating source further includes
 elemental solid aluminum.

7. The method of claim 1, wherein the coating source further includes the elemental solid modifying element.

8. The method of claim 1, wherein the step of contacting the coating source includes the step of

5 providing the fluoride or the iodide of the modifying element separated from the article surface.

9. The method of claim 1, wherein the step of contacting the coating source includes the step of

10 providing the or the iodide fluoride of the modifying element applied to the article surface.

10. The method of claim 1, wherein the modifying element is zirconium.

11. The method of claim 1, wherein the modifying element is hafnium.

12. A method for coating an article, comprising the steps of:
providing the article having a surface, the article being an airfoil;
15 preparing a coating source comprising:

an aluminum halide,

a fluoride of a modifying element as a source of the modifying element,
the fluoride of the modifying element being selected from the group consisting of a
zirconium fluoride and a hafnium fluoride, and combinations thereof, and

20 a carrier gas;

contacting the coating source to the surface of the airfoil; and

heating the coating source and the article to a coating temperature of from about
1850°F to about 2000°F for a period of time sufficient to permit aluminum and the
modifying element to coat onto the surface of the airfoil.

25 13. The method of claim 12, wherein the step of providing the article includes the step of

providing the article with a platinum-enriched surface region thereon.

14. The method of claim 12, wherein the fluoride of the modifying element is zirconium tetrafluoride.

15. The method of claim 12, wherein the fluoride of the modifying element is hafnium tetrafluoride.

5 16. The method of claim 12, wherein the aluminum halide is aluminum trifluoride, the fluoride of the modifying element is zirconium tetrafluoride, and the weight ratio of aluminum trifluoride to zirconium tetrafluoride is from about 1.4:1 to about 3:1.

10 17. The method of claim 12, wherein the coating source further includes elemental solid aluminum.

18. The method of claim 12, wherein the coating source further includes the elemental solid modifying element.

15 19. The method of claim 12, wherein the step of contacting the coating source includes the step of providing the fluoride of the modifying element separated from the airfoil surface.

20. The method of claim 12, wherein the step of contacting the coating source includes the step of providing the fluoride of the modifying element applied to the airfoil surface.

METHOD FOR VAPOR PHASE ALUMINIDING
INCLUDING A MODIFYING ELEMENT

ABSTRACT OF THE DISCLOSURE

5 An article is coated by preparing a coating source having an aluminum halide, a fluoride or an iodide of a modifying element as a source of the modifying element, and a carrier gas. The modifying element is zirconium, hafnium, and yttrium, or combinations thereof. The coating source is contacted to the article, and the coating source and the article are heated to a coating temperature of at least about 1850°F for a period of time sufficient to permit aluminum and the modifying element to coat onto the surface of the article. The preferred fluorides of modifying elements are zirconium tetrafluoride and hafnium tetrafluoride.

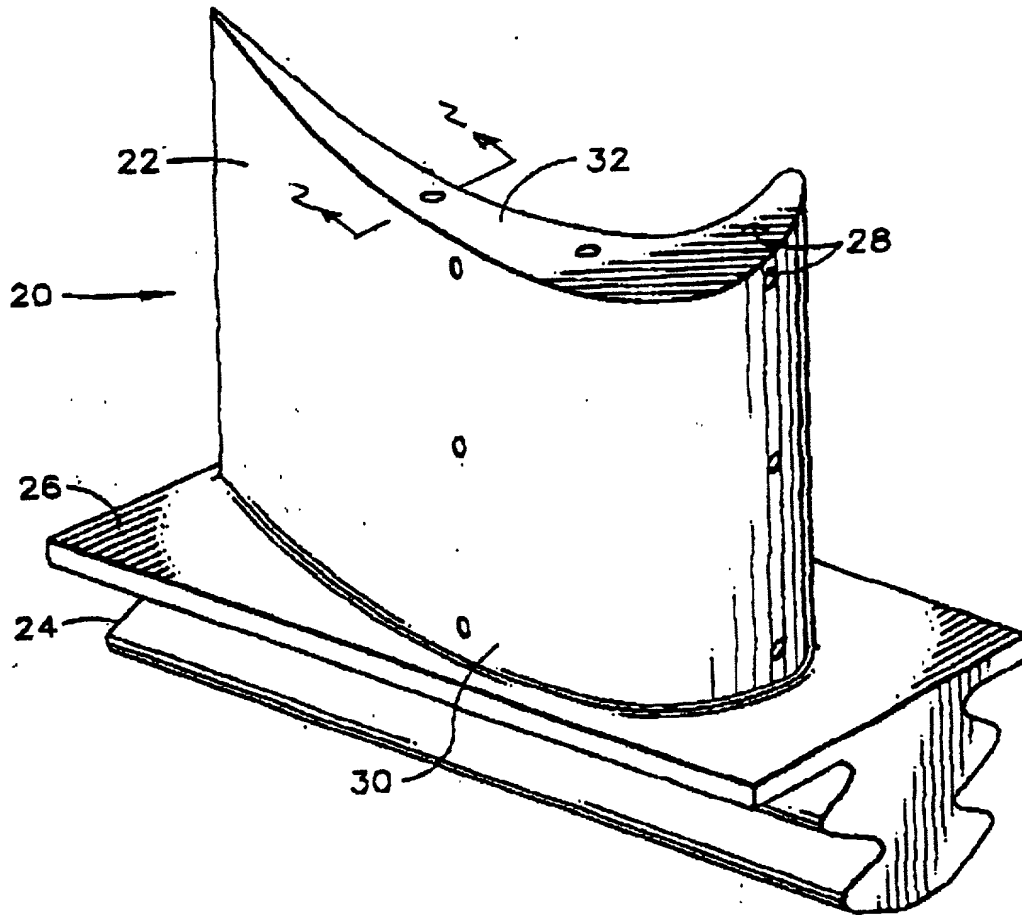


Fig 1

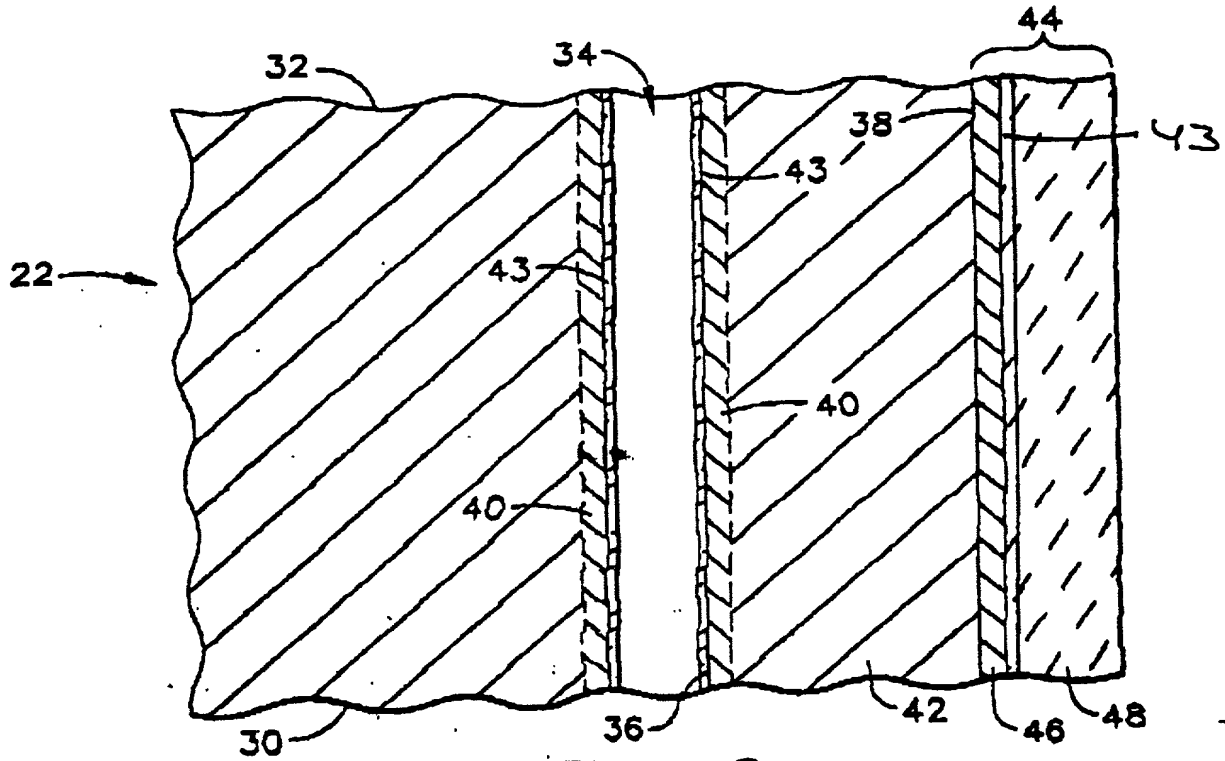


FIG. 2

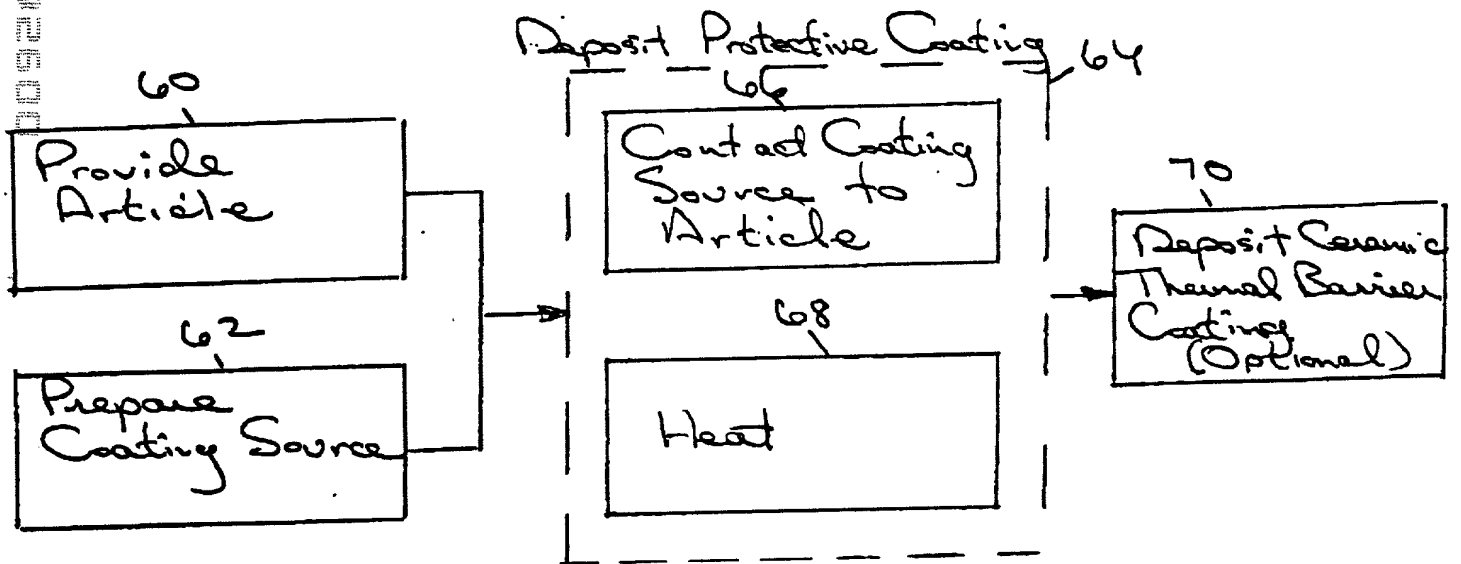


Fig 3

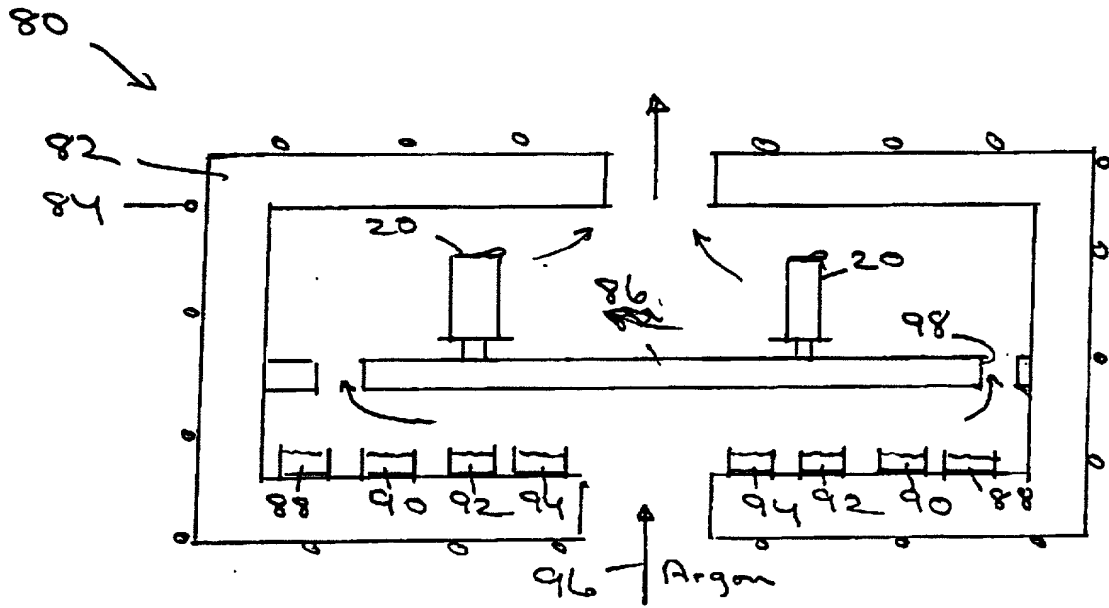


Fig 4

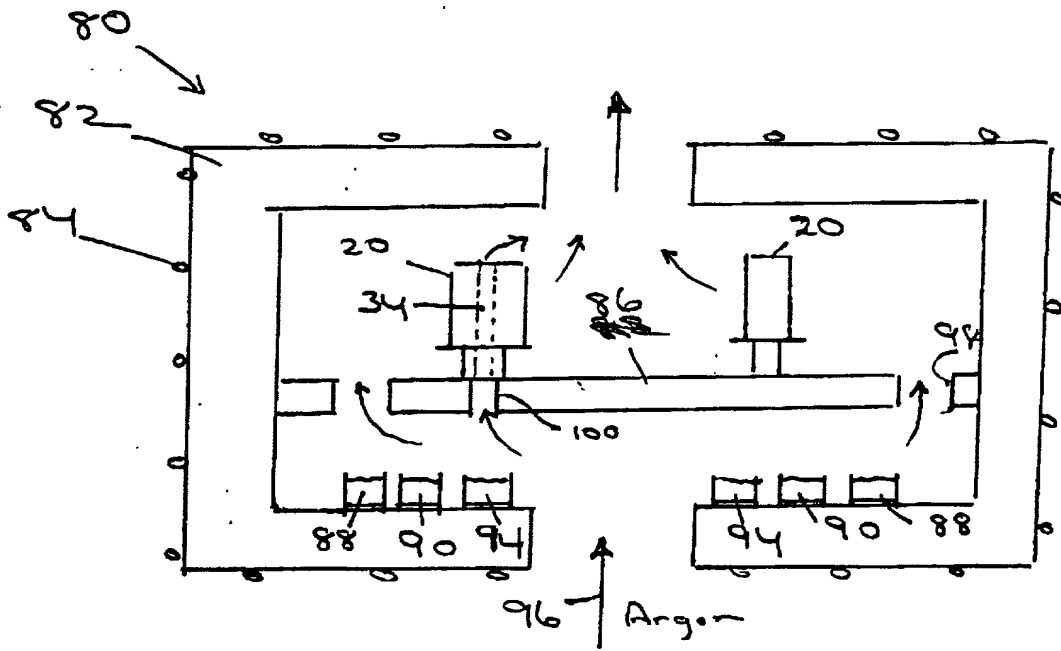


Fig 5

009260" 68707950

**DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION**

Docket Number
13DV13658

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD FOR VAPOR PHASE ALUMINIDING INCLUDING A MODIFYING ELEMENT

the specification of which

☒ is attached hereto
OR

☐ was filed on _____ as United States Application Number or PCT International Application Number _____
and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code §119 (a)-(d) or §365 (b) of any foreign application(s) for patent or inventor's certificate, or §365 (a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN APPLICATION(S)

Priority Claimed

☐ Yes ☐ No

☐ Yes ☐ No

(Number) (Country) (Day/Month/Year Filed)

(Number) (Country) (Day/Month/Year Filed)

☒ Additional foreign application numbers are listed on a supplemental priority data sheet attached hereto.

I hereby claim the benefit under Title 35, United States Code §119 (e) of any United States provisional application(s) listed below.

☐ Additional provisional application numbers are listed on a supplemental priority data sheet attached hereto.

(Application Number) (Filing Date)

I hereby claim the benefit under Title 35, United States Code §120 of any United States Application(s), or §365 (c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

(Application Number) (Filing Date) (Status - patented, pending, abandoned)

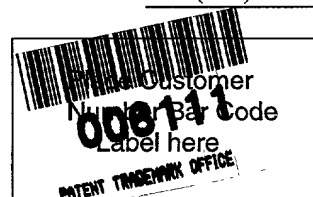
(Application Number) (Filing Date) (Status - patented, pending, abandoned)

I hereby appoint the registered practitioners associated with Customer Number 006111 to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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